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Potential of wind power park in Eastern Finland

A feasibility study

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With the rapid growth of society, people are seeking better, renewable and emission-free energy resources. Finland is not an exception in this race. In fact, green energy is one of its main resources. For example, thousands of wind turbines had been built along the West coast of Finland.

The purpose of this thesis was to study the potential of constructing a wind power park in Eastern Finland. The current position of wind power in Finland and Europe was analysed, and the parameters that need to be taken into account when building wind farms in the proposed area were determined.

Spatial data were manipulated with the GIS software QGIS and presented on a topographic map. Due to the limited of data resources, the project is only tentative and more academic. Thus, more researches and analyses are needed in order to finalise the project.

Keywords	wind power, feasibility study, renewable energy

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List of abbreviations

CORINE	Coordination of Information on the Environment
EU	European Union
GIS	Geographic Information System
NLS	National Land Survey
QGIS	Quantum Geographic Information System

1 Introduction

With the development of society and the increasing concern about climate issues, the necessity of seeking sources of energy that are renewable, environmentally friendly or cost-effective to operate and maintain is more urgent than ever. Besides solar power and other renewable alternative energies, wind power has strengthened its role in this race, especially in Finland (Yle, 2018); a plentiful resource with low maintenance costs and long foreseeable lives. According to the Global Wind Energy Council (n.d.), the total installed wind power capacity reached 539,123 MW globally in 2017, a rise of 10% from last year, where China took the first place with 35%, the United States and Germany both took the second and third position with 17% and 10%, respectively.

The International Energy Agency (2017) predicts that the global wind electricity generation and capacity on land will upsurge by 80% in 2022 (Figure 1) whilst offshore is also expected to grow quickly, especially in Europe and China (Figure 2) (International Energy Agency, 2017).

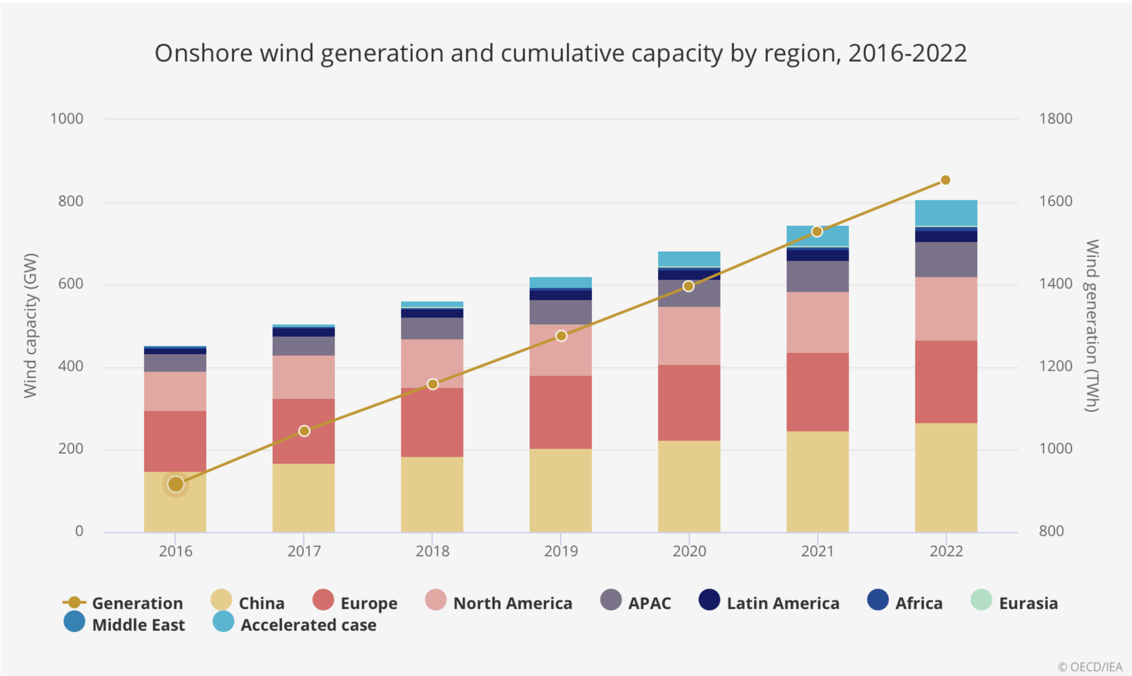

Figure 1. Onshore wind generation and cumulative capacity by region, 2016-2022

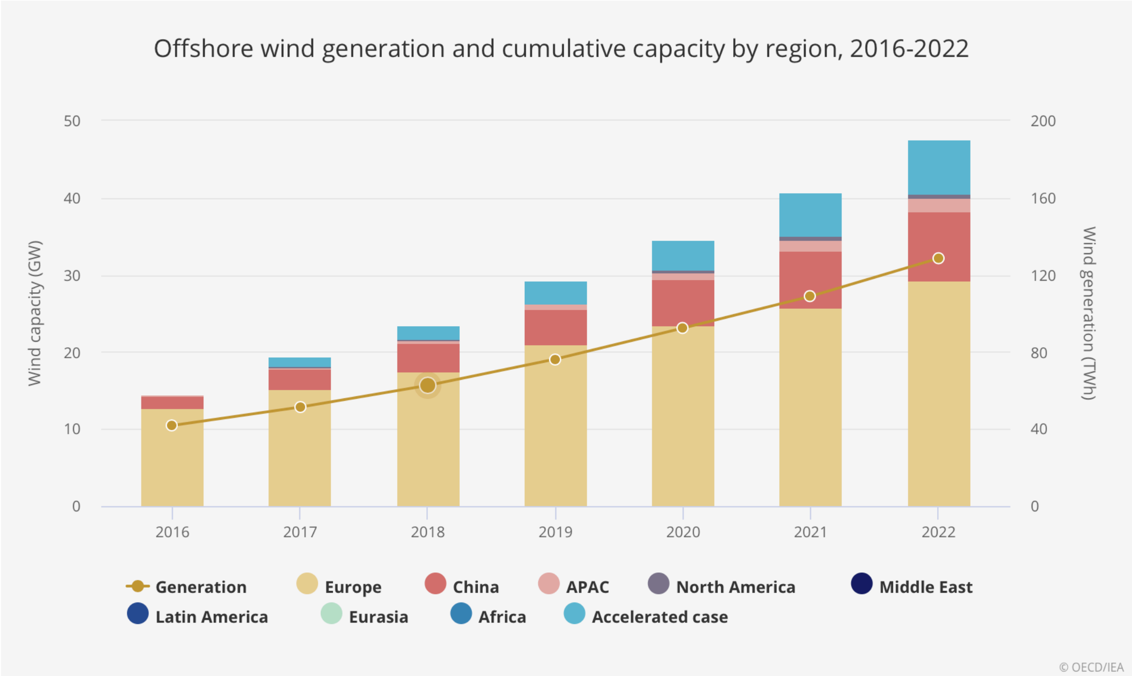

Figure 2. Offshore wind generation and cumulative capacity by region 2016-2022

The purpose of this thesis was to study on the possibility of constructing a wind power farm in Eastern Finland by examining, for example, the topography, soil type, and vegetation of the proposed site. Another aim of the thesis was to gain significant understanding of a 2D GIS system. The approach was to build on existing data rather than on measurements or preliminary research. Thus, the thesis is limited and further research is needed to obtain more conclusive results on the feasibility of wind power in Eastern Finland. Furthermore, the thesis does not focus on the authorisation process such as permitting or financial analysis, but more on highlighting what factors affect the construction and why.

Most of the data used in this thesis were acquired from the NLS of Finland (*Maanmittauslaitos*) – Paikkatietotoikkuna service as well as CSC's PaITuli spatial data service. The data was then processed through QGIS – a free and open source geographic information system software in order to obtain readable figures. In addition, the data are mostly open data and used for academic purposes.

2 Background

Wind power has been developed since the end of the 1970s (Wizelius, 2007). The first large size 12kW wind electricity turbine was built by Charles Brush in 1888 (Kalmikov, et. al., n.d.). By exploiting the lift and drag force from the wind, those turbines collect the kinetic energy and later transform it into electricity. There are 2 types of wind turbine which is Horizontal-Axis Wind turbine (HAWT) and Vertical-Axis Wind turbine (VAWT).

Wind power plants can be easily connected to the national electrical grid via substations. They do not produce any greenhouse gases when in production, maintain low operation cost by not having potentially harmful fuel transportations; they also do not produce any hazardous waste. Moreover, wind turbines can last for approximately 20-25 years, their parts are recyclable which made its an emission-free cycle (Wizelius, 2007).

2.1 Wind energy in Europe

According to the wind power annual report from by the non-profit association Wind Europe (2017), more than 2000 wind turbines have been installed on land with the average size of 3 MW in 2017. Germany dominated in the number of installed turbines; approximately 75% in total. On the other hand, there are comparatively 600 installed offshore wind turbines with the average size of 5 MW and the United Kingdom took the benefit of surrounding by water bodies, 281 wind turbines have been installed; bring Germany to the second position with 222 offshored wind turbines.

Additionally, renewable energy in general and wind power specifically showed astonishing results. There was a growth of 25% from the 2016 annual installations with a 14.3% rise in onshore installations and 101% offshore installations. Moreover, with an enormous 336 TWh produced in 2017, wind power covered 11.6% of EU’s electricity demand on average.

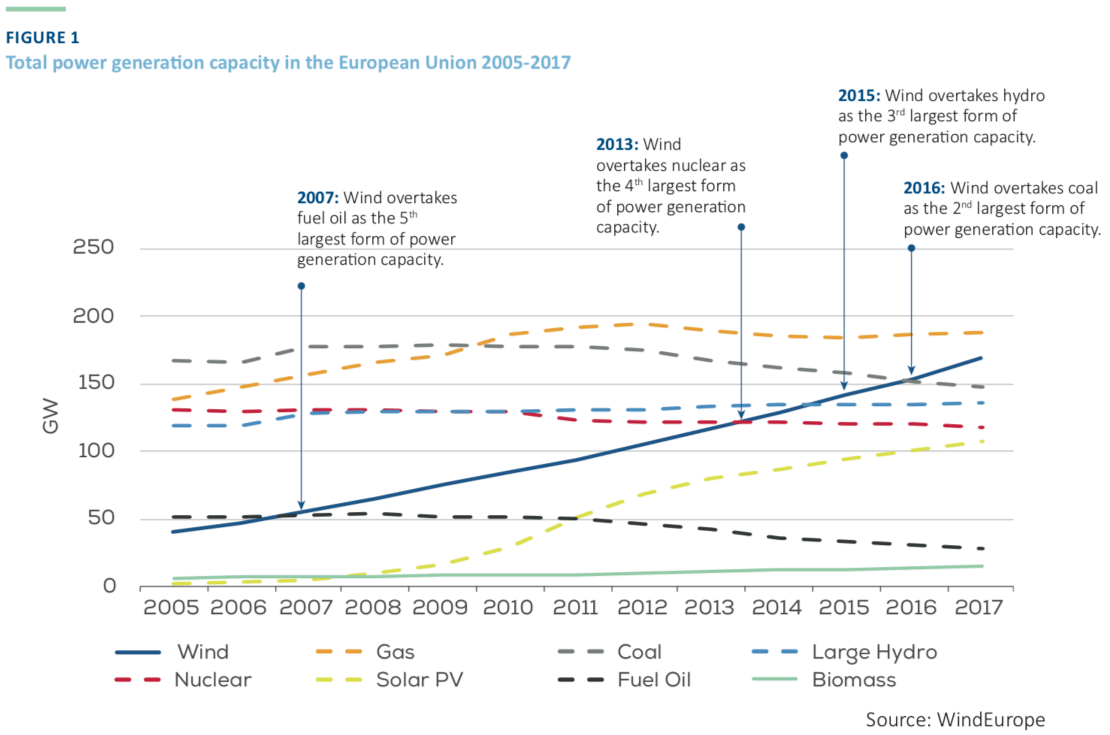

Figure 3. Total power generation capacity in the EU 2005-2017

2.2 Wind energy in Finland

Finland currently has 399 wind farms in total; These are mainly located on the West Coast of Finland and all of them are on shore (Figure 4). According to the Finnish Wind Power Association (2017), at the end of 2017, Finland owned 700 wind turbines with a production capacity of 4.8 TWh and a coverage of 5.6% of the energy consumption in Finland.

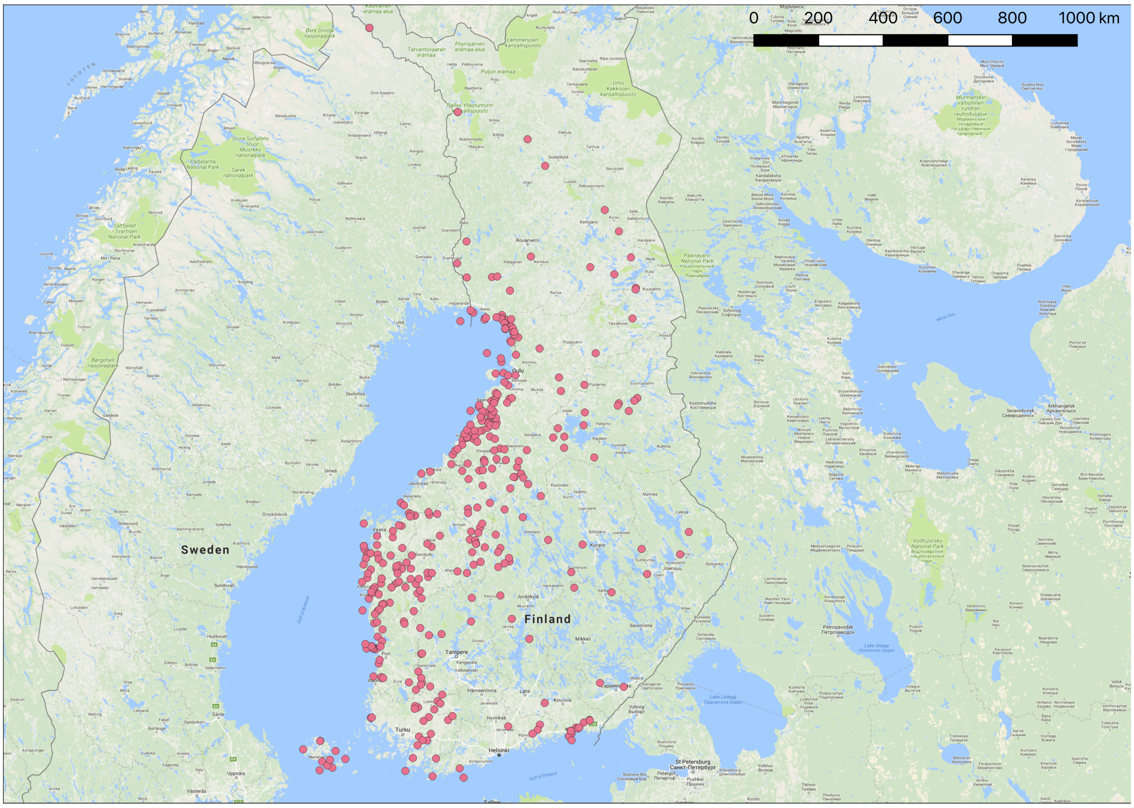

Figure 4. Distributions of wind turbines in Finland (EthaWind, n.d.)

2.3 Study area

The optimal area consists two basic considerations: wind resource availability and presence of wind farms. It also depends on the wind speed which is greatly affected by the geographic location of Finland. With the height of 100m above the sea level and with the power curves of 3 MW turbines, the power production and wind speed have been calculated per annum (Figure 5). These wind atlases are an essential tool for planning and studying the site selection.

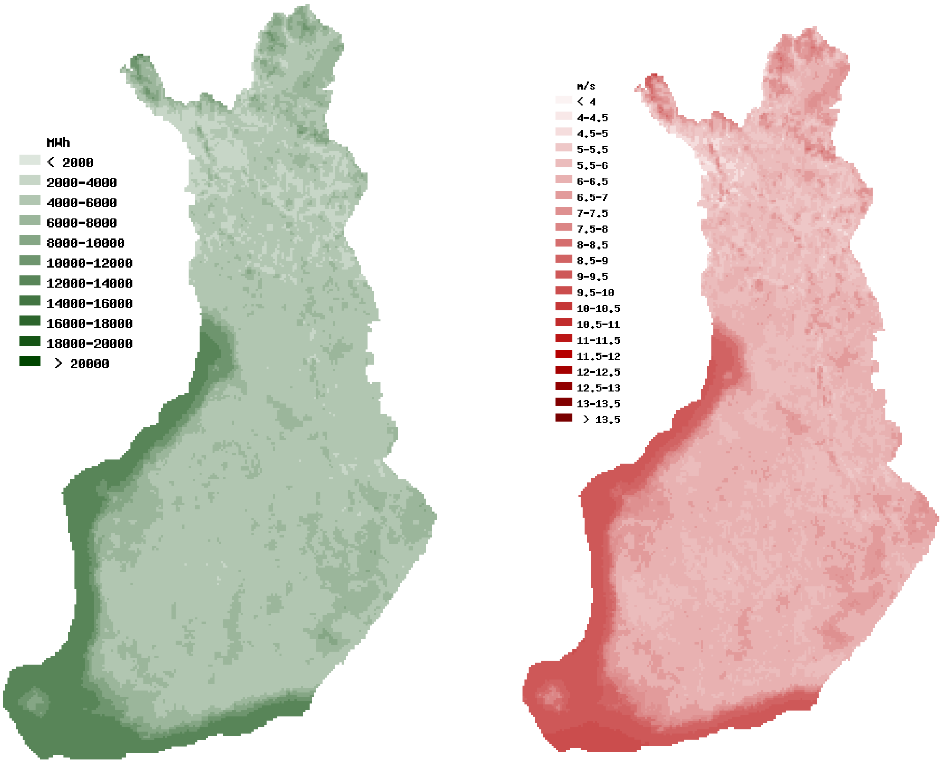

Figure 5. Wind power production and wind speed in Finland

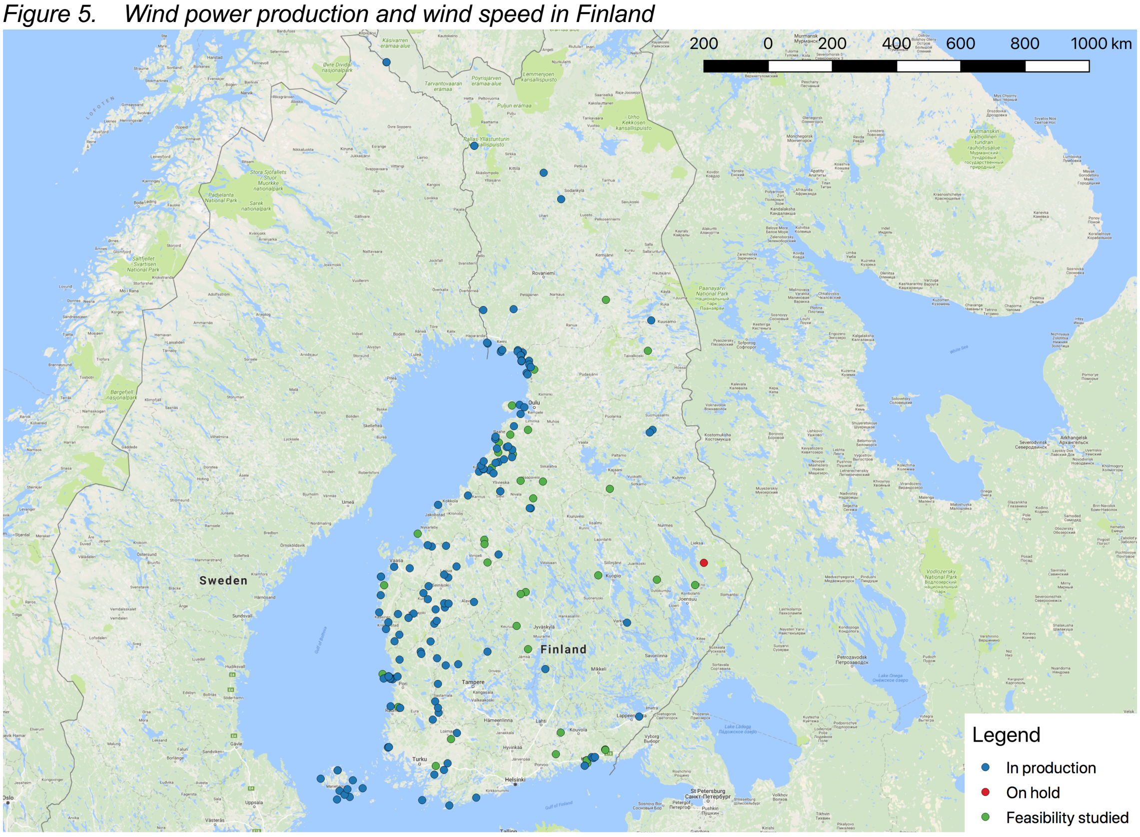

Figure 6. Distribution of wind turbines in production, on hold or under feasibility study (EthaWind, n.d.)

It can be observed from these atlases that the west coast of Finland has the most attractive wind resources available, which is the reason why most of the wind farms are located there (Figure 6). There are also certain areas in Eastern Finland as well as in Lapland that show potential for wind energy. Taking the analysis performed above into account, the area in Eastern Finland close to Finnish and Russian border (Figure 7), which currently has one wind farm project on hold and the feasibility study of another farm underway, was selected as the area to be studied in this thesis.

Figure 7. Research location near Finland – Russian border on the Eastern side of Finland.

The selection of the area to be studied was further supported by the fact that in 2014 Fingrid and the Russian grid parties, Federal Grid Company of the United Energy System and Russian System Operator, signed agreements on a 400-kV cross-border connection

(Nord pool, 2014). Hence, building a wind power park could partly reduce the cost of transfer energy from and to Russia. Furthermore, the closest station of the 400-kV interconnection to the border of Finland and Russia is Varkaus which is at a geodesic distance of approximately 150 kilometres (Fingrid, 2014).

3 Methodology

The thesis project was divided into two separate phases: data preparation and report writing. After being obtained from online services, spatial data were transferred to QGIS where the data were sorted by object class and the most important ones for a topographic map were selected:

- Roads and railroads
- Residential buildings
- Commercial, industrial and other buildings
- Electric grid network
- Conservation area

(More specific information will be shown in Appendix 1)

In reality, there are more variables that need to be considered beside those presented above, but for the purpose of this thesis and due to the unobtainability of more data, these key values will be utilised. After sorting thoroughly, buffer zones were created and dissolved according to the data. Buffer zones act as an ideal area around the objects meaning that areas outside buffer zones are "safe" enough to build the wind power park. The buffer zone sizes shown in the table below were the result of hours of research to find the ideal distance, some of them were also taken from the author's previous project (Tran, et. al., 2017):

Residential buildings	1000m
Commercial/industrial buildings	500m
Roads, railroads, electric grid lines	300m
Natura 2000 areas based on Birds-directive	1500m
Natura 2000 areas based on Habitat-directive	700m

To be more precise, these variables will need to be calculated and measured from the on-site acoustic modelling based on the location of selected area.

To evaluate whether the area was suitable for constructing a wind farm, a linear model or function needed to be developed. Four important parameters involved in the function were wind power production, elevation, slope, and proximity to the roads; all of them will be weighted depending on which parameters would affect the decision the most and which would have the least impact. In addition, the slope had to be calculated beforehand from DEM to validate that the chosen area for wind turbines was not on a mountain nor on impossible slopes because such a location would result in an expensive cost for both financial and construction in the future .To simplify the model, each of the parameters were reclassified in a scale of zero to five, where zero was the least suitable value, and 5 was the most suitable one (Appendix 2).

Besides that, there are many aspects influence on the feasibility of studied area in reality. But for the purpose of this thesis, geography; especially soil types and surrounding environmental habitats are the two essential factors for the evaluation of area of interest.

3.1 Tools

Data used in this thesis were analysed by using QGIS. QGIS is an Open Source Geographic System licensed under the GNU and a major tool for spatial analysis and visualisation. As an open source platform, it is open for everyone to utilise for their own purposes. QGIS runs on the most commonly found operating systems (e.g. Linux, Windows, Mac) and is ideal for both personal and business users (qgis.org, 2018).

3.2 Spatial data

Most of the raw data could be obtained from PalTuli's spatial data services and from NLS of Finland (Maanmittauslaitos). The data were provided as open sources for everyone. However, under certain circumstances, some data are protected and only able to use for educational purposes funded by public means. This thesis is an example of such a purpose.

4 Results

4.1 Topography

The focused area included a conservation area: Koivusuo Strict Nature Reserve, which is a part of Koitajoki Natura 2000 area. This feature has greatly narrow down the amount of space that can be utilised for the wind power park which shows in Figure 8 – buffer zones of the most important data: residential, commercial and industrial buildings, traffic and electric network, and protected areas. However, the area is not densely populated as well as the road and electrical networks are widespread, which allows the flexibility of building a wind power farm in this location.

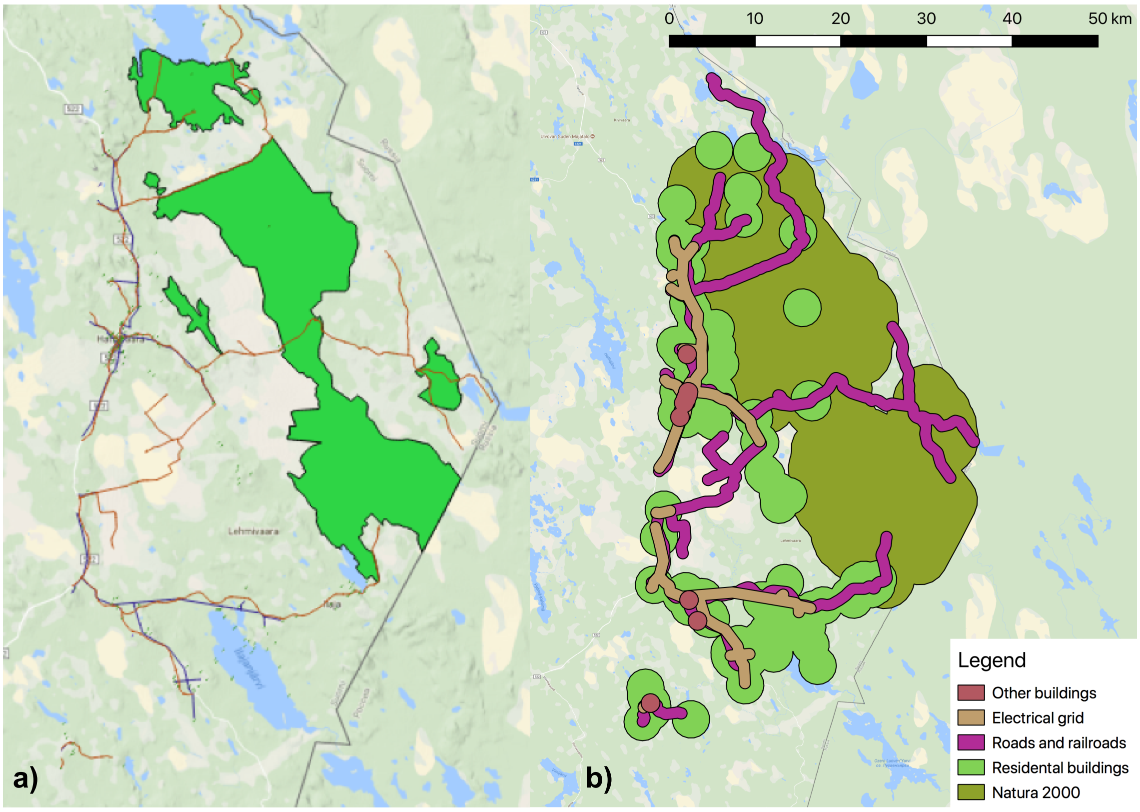

Figure 8. Spatial data before (a) and after (b) applied buffer zones.

With the manipulation of the raster calculator function in QGIS on reclassified data and also with the results from this (Figure 9), the assumingly linear model has been constructed:

0.3 * Wind power production + 0.4 * Elevation + 0.2 * Slope + 0.1 * Proximity to roads

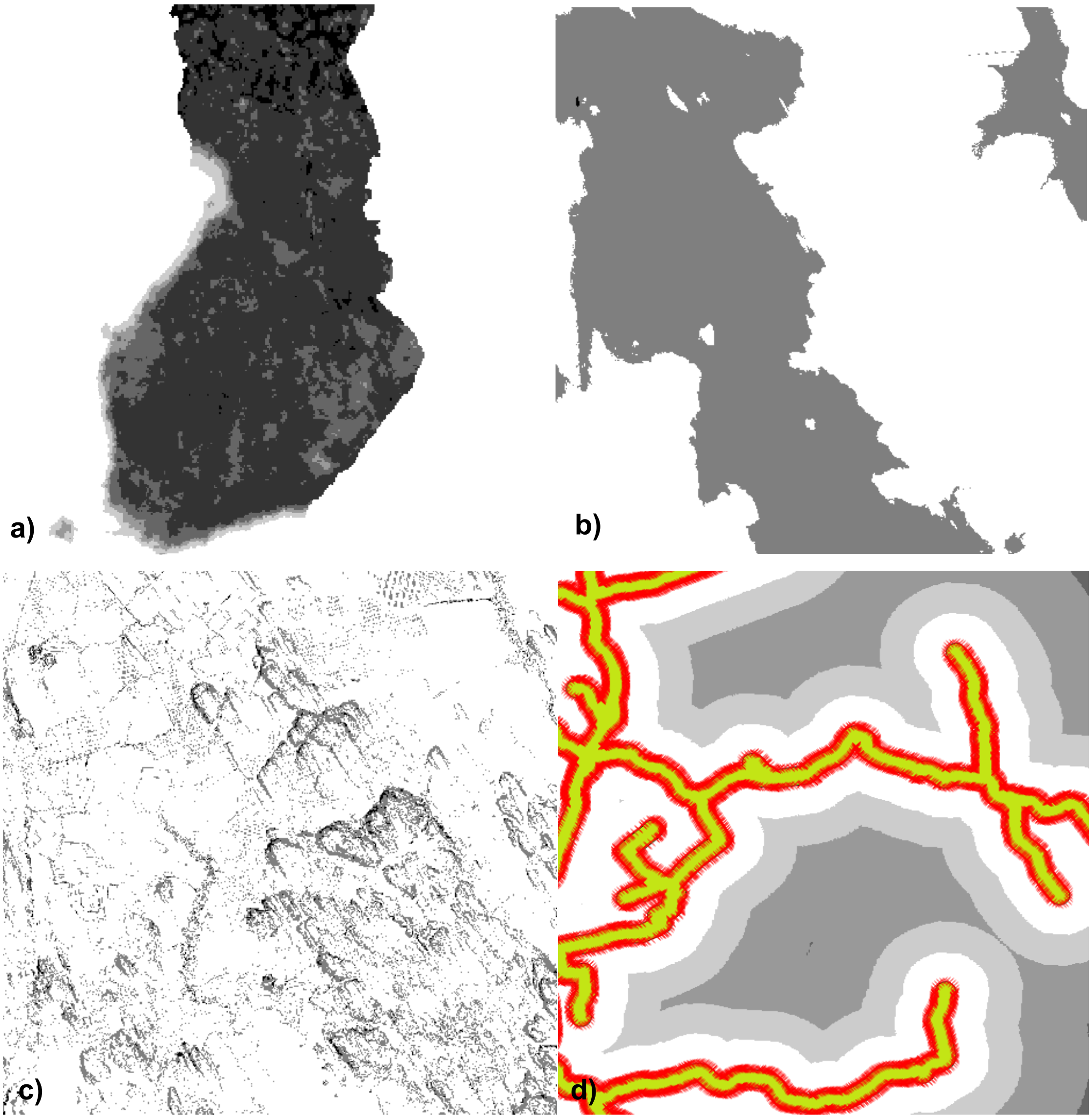

Figure 9. Reclassified wind power production (a), slope (b), elevation (c) and proximity to roads (d).

According to the results, the wind power values were relatively uniform in the area of interest; therefore, it was the second important factor in the function since the more uniformed of the wind; or in other words, the wind speed are strong, the better wind turbines to generate energy. Elevation was the most important factor in the scale of importance as it would directly affect the energy production. It would extremely limit the possibility of building wind turbines, let alone wind farm on such steep locations or sides of the mountains as it would require huge amount of materials and financial to build the foundation. In addition, slope and proximity to the network (which is an assumption for both road and electric grid lines, for example in this case electric lines are located along the roads) would also suggestively influence the finance and feasibility of the project. As a result, it will reduce the loss of energy during the transmission process; however, dealing with existing electric grid lines will be a difficulty when establishing the structure foundation as it can be affected during the constructing phase. You need to explain more in detail, how these results affect the estimated production.

The result of the model falls in the range between 3 and 3.7 on the scale of 5 with 0 is the most unfavourable area and 5 is the most favourable one, which is an average score for the location XX: you need also explain, what is a difference between 0 and five. Figure 10 presents the final result after applying the model to the area with the lighter the colour is on the map, the better and more optimal the area is for placing turbines.

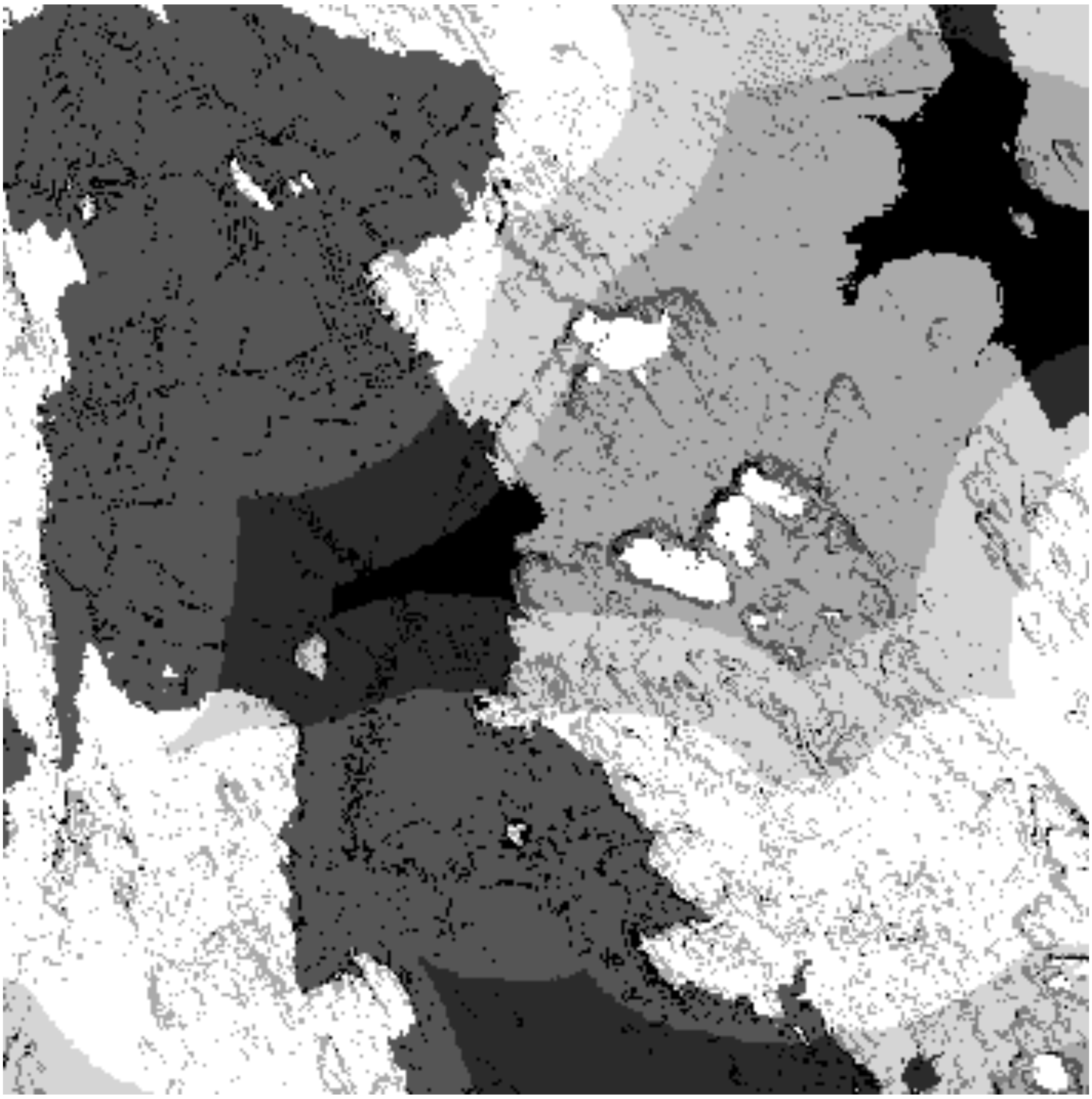

Figure 10. Optimal area map for the wind power park (lighter is better)

By meshing the result with the buffer zones, the final visualised map showing the optimal location ranking for the construction of wind turbines was created (Figure 11). Additionally, several aspects such as prevailing wind direction, turbulence and wake effects need to be considered during the placement of turbines. According to the information on Finnish Wind Atlas service (n.d.), the predominant wind direction in Finland is south-west. Also, the turbine should be placed at a long enough distance from any of the obstacles and between each turbine, to reduce the possibility of the turbulence as well as the turbines should be placed in an “arrow” to limit the wake effect will significantly eliminate efficiency loss and unnecessary fluctuations during the energy production of wind turbines (Sanguri, et. al., 2010). To avoid the confusing and difficult-to-understand colours, all colours were kept muted with the scheme of the darker the area, the less desirable it is for constructing a wind power park.

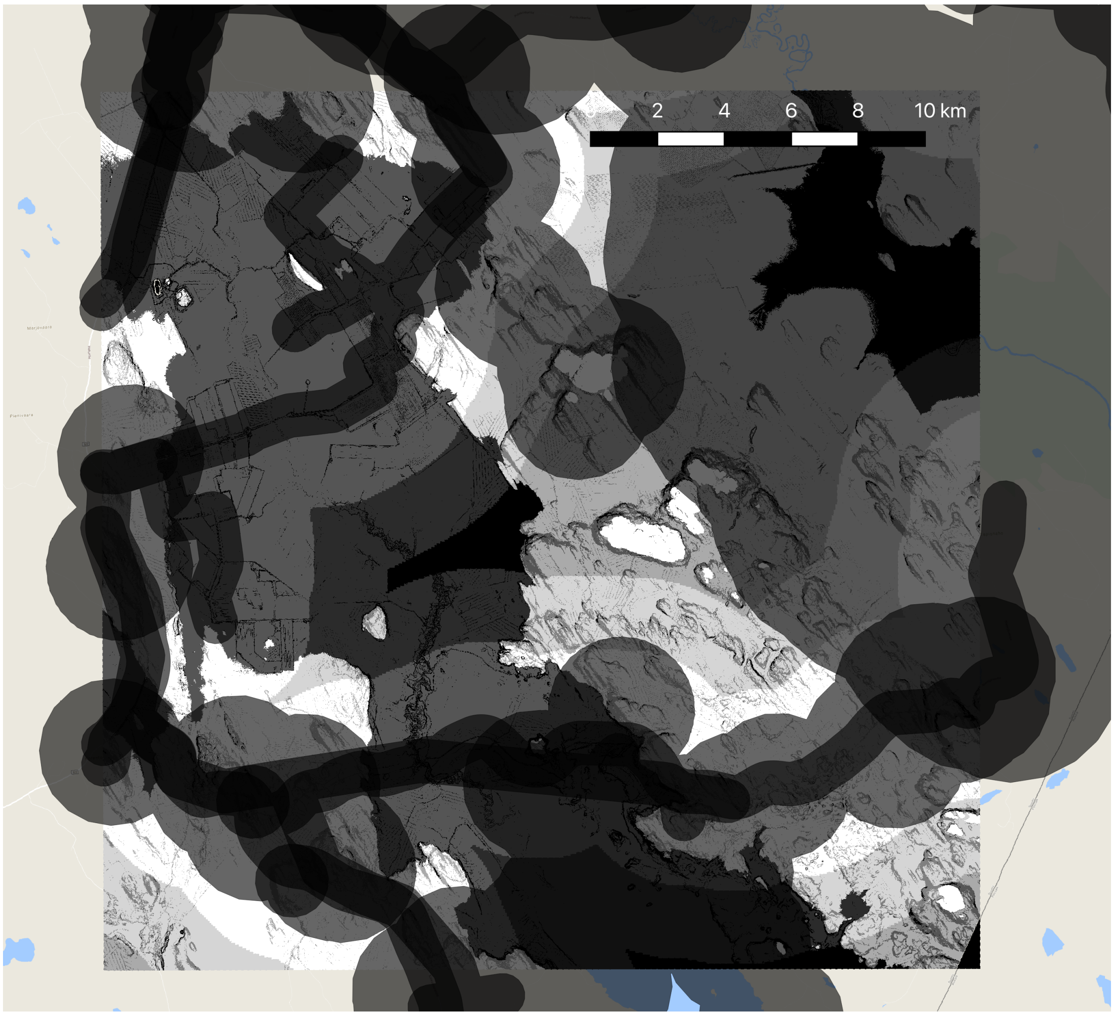

Figure 11. Combination of buffer zones and optimal area map.

4.2 Geography and Habitats

Besides topography, soil type and surrounding environmental habitats also play a critical role in order to build a wind farm. The characteristics of soil will determine the possibilities when planning the foundation as well as current habitats in the area.

According to the data retrieved from NLS of Finland (2018), approximately 60% of the land is Histosols, 30% is Podzols and 10% is other soil types in the studied location (Figure 12). Histosols are well known for their poor drainage, very low bulk density, usually between 0.05 and 0.1 Mg/m^3, as well as acidity, formed by the incomplete decomposition of organic materials and have various names, such as muck or peat (Driessen, Dudal, 1989). Due to these characteristics, heavy structures that are built on tend to subside in this wet and soft soil. On the other hand, podzols are badly for decomposed organic matter, formed under damp and acidic conditions with the parent materials such as granite or quartz. As a result, podzols have low or very low clay content and great sandy portion which leads to low level of moisture (Driessen, Dudal, 1989).

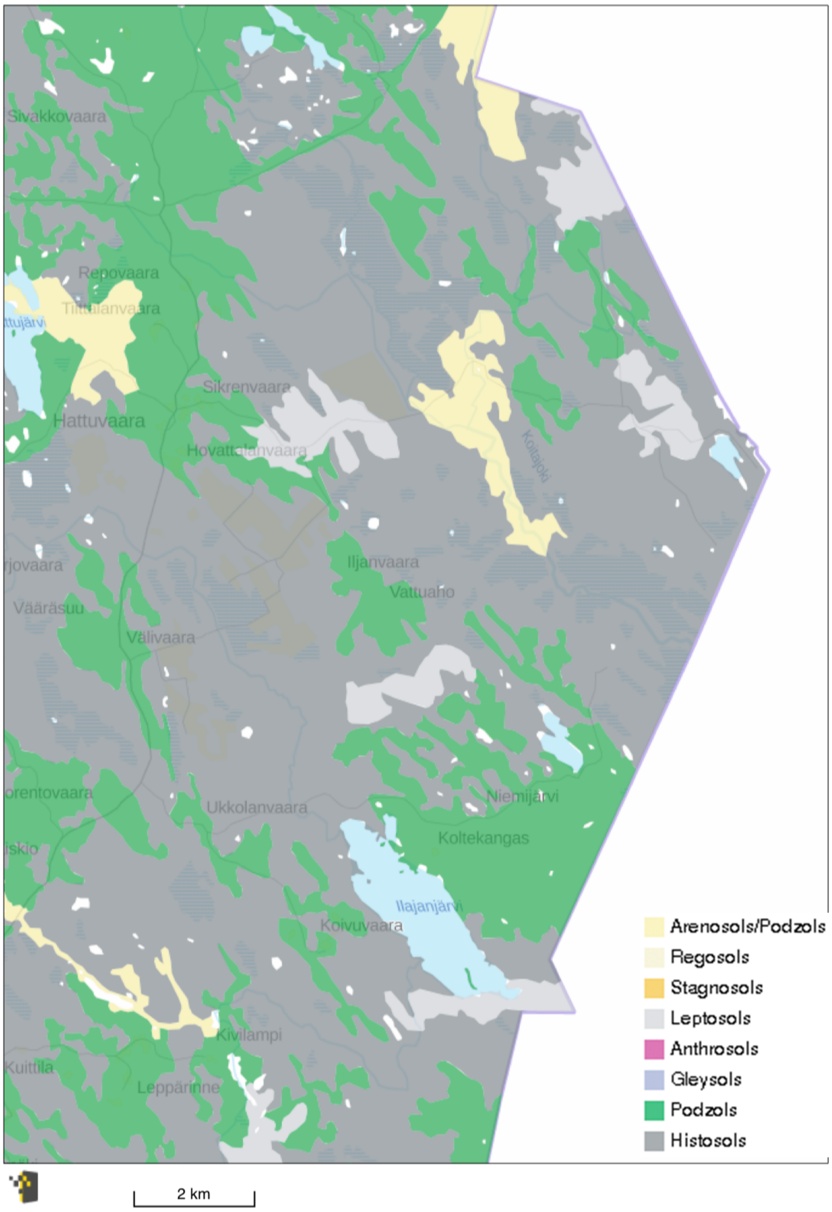

Figure 12. Soil types in Eastern Finland

The surrounding environmental habitats also significantly effects the proposal. The location is mostly covered in different types of forest in accordance with CORINE land data from Finnish Environmental Institute. A predominant portion of the studied area is coniferous forest, natural grasslands as well as bogs/peat production areas. Additionally, peat production still accounts for a considerable portion of heat and energy production in Finland. (Silpola, 2017).

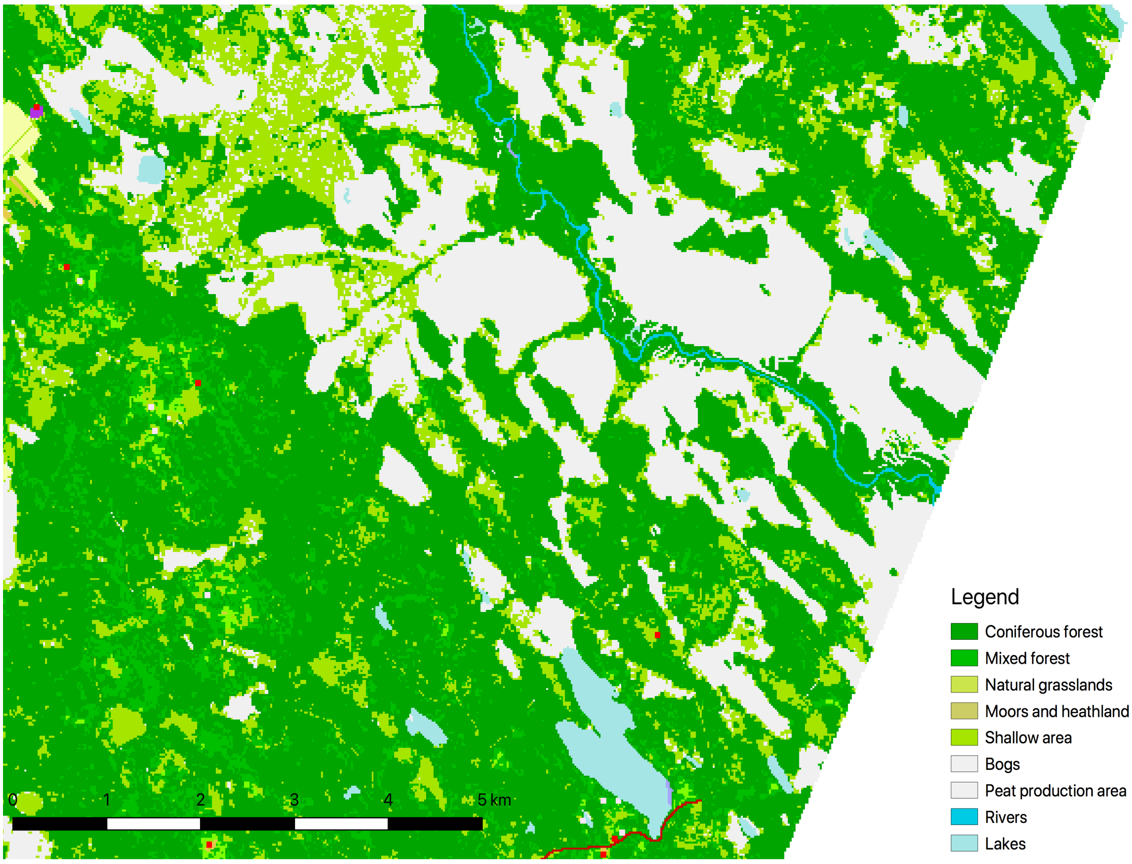

Figure 13. CORINE land data in Eastern Finland

Considering all the above-mentioned facts and data together with the visualised topographic map, the most ideal area for the purpose of constructing the wind farm in this location is on the right side of Ilajanjärvi. With the foundation layer of podzols and mainly surrounded by peat production areas, it will be a major shift to renewable and emission-free energy from the high global warming emissions and environmental concerns of the peat energy source.

5 Conclusion

According to the analysis, the studied location has its own advantages and drawbacks. On the basis of the model value output in the range of 3 to 3.7, the area is confidently within the potential average for planning a wind power park. However, realistically thinking, the application of the electricity produced by the wind farm can be debatable. The nearby area is not densely populated and covered with residential, commercial and industrial buildings. It is a benefit in terms of noise pollution. The location is covered adequately with different kind of vegetation habitats. The losses during transfer energy over transmission lines can happen. Yet, numerous other analyses should be executed to get an overview of the project's practicability and to determine whether the foundation of the wind farm would need any additional reinforcements.

As indication throughout the thesis, there are still many areas that needed to primary research and study to make the project feasible. For instance, the linear model of raster calculation was based on the author assumption and secondary research as well as the buffer zone distances. Also, the amount of data used in this thesis is only the key and general factors, there are many details that have been excluded from this thesis, which may make a huge different in the results. There is no information in regards of regulations and permits, no information on how the weather will affect the area, no due diligence survey done in the community, configuration changes due to the difference from research versus reality, and it continues.

The aim of this study was to develop a better understanding of the potential of wind power in Eastern Finland and also gain practical experience in manipulating spatial data by utilising GIS software. Therefore, learning data analysis and tools played an important role in this thesis project. Furthermore, certain data were unobtainable, which is a limitation for the thesis and to cover it in the large scale will beyond the scope of thesis as the study was based on existing research data.

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Appendix 1: Details of key topographic database

Specific information of which object classes had been chosen in each key parameter. The data was originally in Finnish and being translated in English for clarification. (NLS of Finland, 2016).

- Roads and railroads
    - Autotie Ia
    - Autotie Ib
    - Autotie IIa
    - Autotie IIb
    - Autotie IIIa
    - Autotie IIIb
    - Railway
    - Narrow-gauge railway

- Residential Buildings
    - Residential building with unspecified storey
    - Residential building with 1 – 2 storey(s)
    - Residential building with 3 storeys
    - Cottage, unspecified storey
    - Cottage, 1 – 2 storey(s)
    - Cottage, 3 storeys

- Commercial, industrial and other buildings
    - Industrial building, unspecified storey
    - Industrial building, 1 – 2 storey(s)
    - Industrial building, 3 storeys
    - Commercial or public building, unspecified storey
    - Commercial or public building, 1 – 2 storey(s)
    - Commercial and public building, 3 storeys
    - Church/Cathedral
    - Church building, unspecified storey
    - Church building, 1 – 2 storey(s)
    - Church building, 3 storeys
    - Other, unspecified storey
    - Other, 1 – 2 storey(s)
    - Other, 3 storeys

- Electric grid lines
    - Medium voltage (20 kV and above but less than 110 kV)
    - High voltage (110 kV and above)

Appendix 2: Data reclassification rules

Wind power production:

```
 88 = 5
110 = 4
133 = 3
155 = 2
177 = 1
199 = 0
```

Elevation:

```
  0 thru 100 = 0
100 thru 120 = 1
120 thru 150 = 2
150 thru 170 = 3
170 thru 210 = 4
210 thru 230 = 5
```

Slope:

```
  0 thru 0.7 = 5
0.7 thru 1.5 = 4
1.5 thru 2.2 = 3
2.2 thru 2.7 = 2
2.7 thru 3.4 = 1
3.4 thru 3.8 = 0
```

Proximity to the electrical and traffic network:

```
   0 thru 1000 = 5
1000 thru 2000 = 4
2000 thru 4000 = 3
4000 thru 6000 = 2
6000 thru 7500 = 1
7500 thru 9300 = 0
```